Sensor Data Integrity and Mitigation of Perceptual Failures

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1 Scientific objective of the research

The general objective is to better understand and promote integrity and dependability of perceptual systems for unmanned ground vehicle (UGV) systems, to provide them with the ability to achieve long-term autonomous operations in off-road environments, including (and in particular) in challenging conditions.

2 Approach

2.1 Background

In the first part of this project, in 2008, large amounts of synchronised data were gathered from a representative UGV platform using a wide variety of sensing modalities (Fig. 1). These modalities included a visual camera, an infrared (IR) camera, laser range finders and a mm-wave radar. The data sets were collected from a UGV in the presence of challenging environmental conditions (such as the presence of airborne dust, smoke, rain). The collected data were then published, and are now extensively used for the developments of this new project.

2.2 On-going work

The approach is composed of the following components.

1. Analysis of the gathered multi-sensor data (see Section 2.1) to evaluate the performance of various sensor modalities depending on situations and types of challenging environmental conditions.

2. Exploration of multi-modal redundancy for the mitigation and/or detection of perceptual failures, specifically between laser and radar.

3. Characterisation of failures in a typical UGV system (Fig. 2), and exploration of possible related indicators.

4. Study of diagnosis techniques to detect failures in the system using aforementionned indicators as information input.

5. Investigation into techniques of reconfiguration to recover from possible failures, using a multi-mode approach.

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14. ABSTRACT
In the first part of this project, in 2008, large amounts of synchronised data were gathered from a representative UGV platform using a wide variety of sensing modalities (Fig. 1). These modalities included a visual camera, an infrared (IR) camera, laser range finders and a mm-wave radar. The data sets were collected from a UGV in the presence of challenging environmental conditions (such as the presence of airborne dust, smoke, rain). The collected data were then published, and are now extensively used for the developments of this new project. The general objective is to better understand and promote integrity and dependability of perceptual systems for unmanned ground vehicle (UGV) systems, to provide them with the ability to achieve long-term autonomous operations in off-road environments, including (and in particular) in challenging conditions.

15. SUBJECT TERMS
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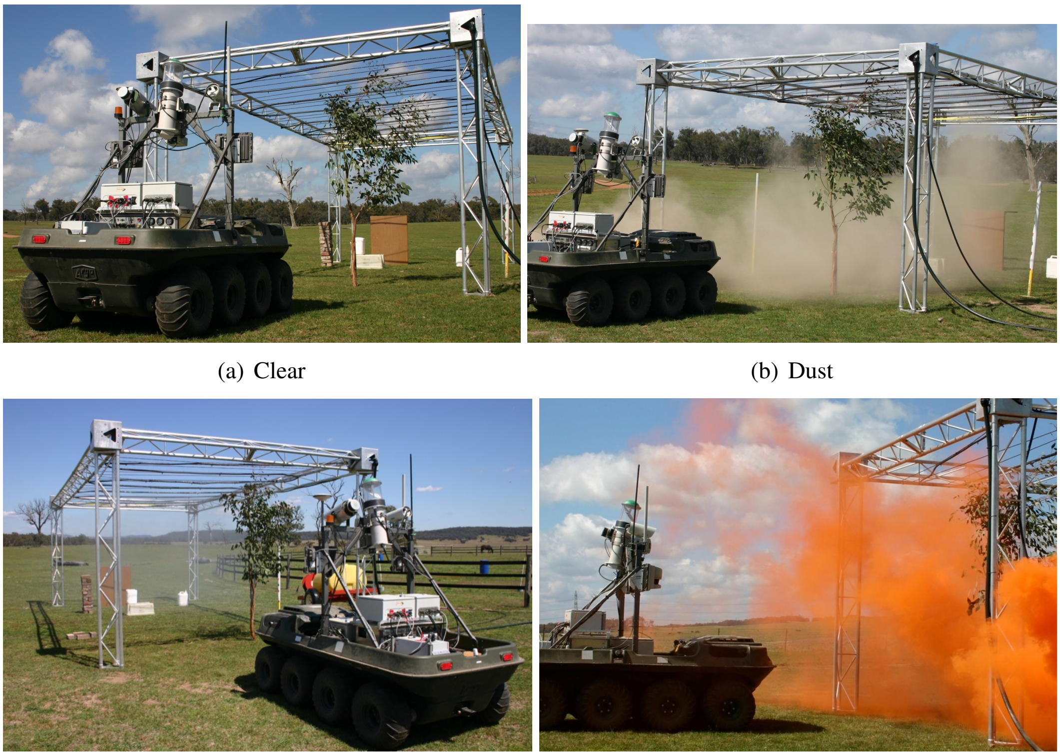


(a) Clear

(b) Dust

(c) Rain

(d) Smoke

Figure 1: The ACFR Argo UGV sensing the trial area, in challenging environmental conditions.

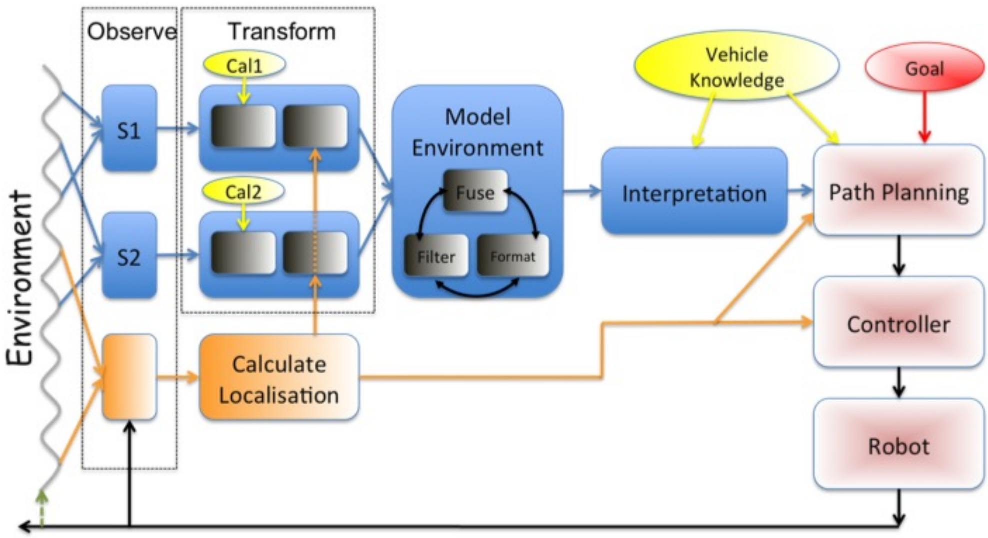
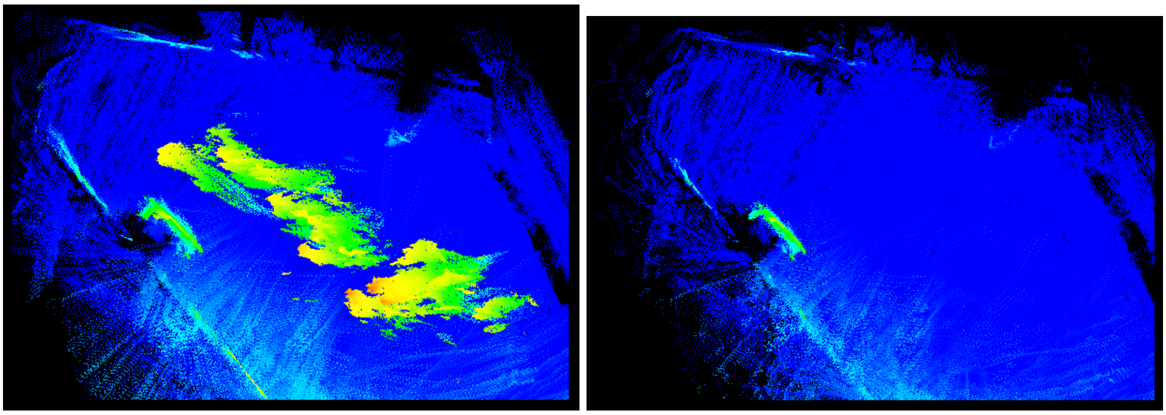


Figure 2: Typical UGV system: functional description.



(a) Raw laser data (b) Filtered laser data

Figure 3: A 3D point cloud of the laser points gathered by a moving UGV, shaded by elevation (bird's eye view). On the left, all of the data is displayed and the area that is affected by airborne dust can be seen in the centre of the scene. On the right, the points that have been classified as dust by the model have been removed. The dust cloud has been filtered, yet the car to the left of the scene and most of the wall and fence line remain.

3 Progress made in 2010

1. The sensor data analysis was achieved, following the data gathering effort. Some of the conclusions are the following. The SICK laser used on the UGV is consistently returning points from airborne dust and smoke clouds, making it inappropriate in these conditions. Some points are also returned due to rain drops, although these could be relatively easily filtered. The mm-wave radar, although less accurate than the laser, can maintain a consistent image of the actual obstacles in the environment in the presence of dust, smoke, or rain, only suffering from a slight attenuation of the signal. The visual images are highly affected by dust and smoke, while the IR camera consistently sees through smoke.

2. Preliminary work at ACFR exploited the comparison of laser and radar range data to cross-validated laser data [3]. However, this method assumed the alignment of the sensors and was specifically designed as and airborne dust filter (Fig. 3), which limited its utility and applicability. Following this preliminary study, an enhanced method has been developed, which provides a better analysis of radar data, and a more robust comparison of data without making the hypothesis of alignment of the sensors. Indeed, this method exploits more information from each radar scan than the common approach to only extract the points corresponding to the highest peak of intensity at each scanning angle. Besides, it uses the result of a process of calibration in order to compare data in a common frame, which means the method accounts for the difference in the alignment of the sensors. This new method is currently under experimental evaluation.

3. A functional description of a typical UGV system, based on the ACFR Argo UGV, was derived (see Fig. 2). On this model, various typical failures were identified and a number of simple possible indicators were considered (see Fig. 4).

4. Collaborators in the field of diagnosis of engineering systems were consulted (during a visit at a University in France), and an initial proposition of a distributed diagnosis system that could

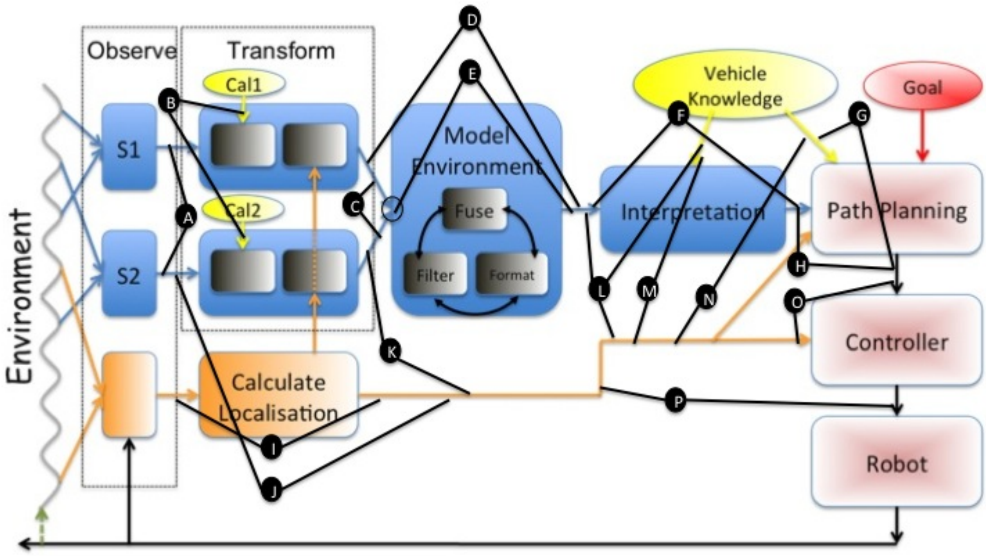


Figure 4: UGV system: Identified redundancies.

apply to the previous model has been made.

5. Following (and reconsidering) previous work by the PI of this project [2], an initial application on an indoor platform has been proposed, as a proof of concept, before future deployment on a UGV platform for off-road operation. The design, adaptation and implementation of the technique on this platform have been made, and experimental tests are currently conducted.

4 Publications made in 2010

A paper on the multi-modal sensor data sets has been published in one of the highest ranked journals in robotics: The International Journal of Robotics Research, in November 2010 [1].
Publications related to items 2 and 5 are currently being prepared.
Note that a related paper had been published in 2009, in anticipation for this project [3].

5 Significance of this research

This research should provide a UGV with better (more reliable) ability to achieve long-term autonomous operation in various off-road conditions, including in challenging environmental conditions. In particular, it is expected to provide some *guarantees* of high integrity and a required degree of *self-awareness*.

References

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[2] Thierry Peynot and Simon Lacroix. *Experimental Robotics: The 10th International Symposium on Experimental Robotics*, chapter Selection and Monitoring of Navigation modes for an Autonomous Rover. Springer-Verlag, 2008.

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